RECORD OF DECISION

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MARS EXPLORATION ROVER–2003 (MER–2003) PROJECT ENVIRONMENTAL IMPACT STATEMENT (EIS)

A. Background

The MER–2003 project consists of two missions to send two identical mobile science laboratories (rovers) to two different sites on the surface of Mars to conduct in situ mineralogy and geochemistry investigations and to characterize a diversity of rocks and soils which may hold clues about past water activity. The year 2003 represents a uniquely efficient launch opportunity for a surface mission to Mars in the next 20 years. Each rover will explore to a distance of at least 600 meters from its landing site (with a goal of one kilometer). Surface operations for each rover are expected to last at least 90 Martian days (sols), and the two rovers will operate simultaneously for at least 30 sols. The rovers will investigate up to a total of eight separate locations in the vicinity of two diverse landing sites. Specific landing sites have not yet been selected, but potential sites between 15° South and 5° North for the MER–A mission, and between 10° South and 10° North for the MER–B mission, are currently being considered.

The scientific goal of the MER–2003 project is to determine the aqueous, climatic, and geologic history of two sites on Mars where water may have been persistent, thus creating conditions for potential habitats. Accordingly, the broad scientific objectives for each mission are to:

- identify the hydrologic, hydrothermal, and other processes that have operated at the landing site and affected the materials there, using measurements of their mineralogy, elemental chemistry, and surface texture;
- identify and investigate Martian rocks and soils that have the highest possible chance of preserving evidence of ancient environmental conditions favorable to life; and,
- use the tools that were designed for the above objectives to respond to other discoveries associated with rover-based exploration.

Furthermore, the MER–2003 project will allow NASA to substantially advance its technological and operational capabilities on the surface of Mars. Mission-level objectives include, but are not limited to:

- demonstrate long range traverse capabilities by mobile science platforms to validate long-lived, long distance rover technologies;
- demonstrate complex science operations through the simultaneous use of multiple science-focused mobile laboratories; and
- validate the standards, protocols, and capabilities of the international Mars communications infrastructure.

B. Introduction to the EIS

This EIS was developed to address all major elements of the MER–2003 project. NASA published a Notice of Intent on February 22, 2001 in the *Federal Register* (66 FR 11184) to prepare an EIS and conduct scoping for the MER–2003 project. The scoping period ended April 9, 2001. Two scoping comments were received from private individuals expressing concerns about the use of plutonium in space missions, and were considered in development of the Draft EIS (DEIS).

NASA published its Notice of Availability (NOA) for the DEIS on July 24, 2002 (67 FR 48490), and mailed copies to Federal, State and local agencies, organizations, and individuals. In addition, NASA made the DEIS available in electronic format on its website. The U.S. Environmental Protection Agency (EPA) published its Notice of Availability on July 26, 2002 (67 FR 48894), initiating the 45-day review and comment period, which closed on September 9, 2002. Six comment letters were received, and included “no comment”, requests to clarify specific points of discussion in the text, and an objection to the use of nuclear material in space. These comments were considered in development of the Final EIS (FEIS).

NASA published its NOA for the FEIS on December 10, 2002 (67 FR 75863) and mailed copies to Federal, State and local agencies, organizations, and individuals. In addition, NASA made the FEIS available in electronic format on its website. The EPA published its NOA on December 13, 2002 (67 FR 76740), initiating the 30-day waiting period, which ended on January 13, 2003, but which NASA extended to January 15, 2003. One hundred sixty one (161) pieces of correspondence, in the form of e-mails and letters, were received by NASA during this period. This correspondence neither raised new issues nor provided any additional data or information relevant to the adequacy of the FEIS, but in part reiterated views previously asserted against the use of nuclear material in space. Concerns raised in the correspondence are addressed in the appendix to this Record of Decision.

The EPA published a finding of no objection to the Proposed Action regarding NASA’s FEIS on January 24, 2003 (68 FR 3526).

Alternatives Considered

The alternatives addressed in the EIS were:

1. The Proposed Action, which would continue preparations for and implement the MER–2003 project to Mars. The MER–2003 project involves two launches (the MER–A mission and MER–B mission) of identical spacecraft from Cape Canaveral Air Force Station (CCAFS), Florida, in 2003. The MER–A launch, aboard a Delta II 7925, would occur during May or June, 2003. The MER–B launch would occur during June or July, 2003, aboard a Delta II 7925 Heavy. This alternative would accomplish all of the desired science and mission objectives established for the project. The Proposed Action was designated NASA’s preferred alternative in NASA’s NOA for the FEIS, published December 10, 2002 in the *Federal Register*.

2. The No Action Alternative, which would result in termination of preparations for the MER–2003 project. None of the scientific objectives planned for the project would be achieved,

and the objectives of NASA's planned follow-on missions to Mars would be adversely affected.

In addition to the basic engineering design of the spacecraft, the other key components associated with the MER–2003 project are the number of launches and the system for maintaining the spacecraft's thermal environment. These key components were considered in the EIS in terms of their ability to satisfy the science and mission objectives of the project, and their potential for reducing the postulated environmental impacts associated with the project.

The evaluation of project components led to the following determinations. Launching only a single mission would not allow NASA to complete all mission objectives. Specifically, a single mission would not allow for (1) exploration of two diverse landing sites, (2) demonstrating complex science operations through simultaneous use of multiple rovers, (3) taking full advantage of the uniquely efficient 2003 launch opportunity to Mars, and (4) maximizing NASA's chances for successfully landing rovers on the surface of Mars. However, programmatic issues *(e.g.*, changes in NASA priorities or unforeseen circumstances) could cause modification to the mission objectives and timing. Such modifications could result in the need to launch one mission in 2003, and a second mission at a later launch opportunity or not at all. If any of these events were to occur, NASA will evaluate the need to prepare additional environmental documentation.

Each rover requires eight (8) plutonium dioxide-fueled radioisotope heater units (RHUs) to satisfy thermal requirements on the surface of Mars. NASA's Jet Propulsion Laboratory conducted an analysis of available thermal control techniques to reduce or eliminate the RHUs, including reducing heat loss from the rover, operating electric heaters with the rover's batteries, and operating electric heaters via a lander power umbilical. None of these techniques were found to efficiently support the mission lifetime and operational requirements. For example, it is estimated that the mission duration for a MER–2003 rover using only electrical heaters powered by the batteries would last a maximum of 16 sols, considerably less than the 90-sol duration requirement.

Key Environmental Issues Evaluated

The key environmental issues of implementing the Proposed Action are those associated with the air emissions which will accompany normal launch of the two MER–2003 spacecraft, and the environmental consequences (both radiological and nonradiological) associated with potential launch accidents. The environmental impacts of normal launches of the two missions for the MER–2003 project will be associated principally with the exhaust emissions from each of the Delta II launch vehicles.

Accidents could occur during preparations for and launch of any launch vehicle. Only two types of nonradiological accidents would have potential off-site consequences: a liquid propellant spill during fueling operations, and a launch failure. A launch vehicle accident either on or near the launch pad within a few seconds of liftoff presents the greatest potential for impact to human health, principally to workers at the launch site.

Each MER–2003 rover will have 8 RHUs, which use plutonium dioxide (consisting of mostly plutonium-238 (Pu-238)) to provide heat to prevent the electronics and batteries from freezing during the Mars night. The total plutonium dioxide inventory on each rover could be up to about

266 curies at the time of launch. Each rover would also carry small-quantity radioactive sources (up to 0.35 curies of cobalt-57 (Co-57) and up to 0.05 curies of curium-244 (Cm-244)) in two of its science instruments. Depending upon the sequence of events, some launch accidents could result in release of some of these materials.

There would be no environmental impacts associated with the No Action Alternative.

Environmental Consequences of the Alternatives

In considering the consequences of the alternatives, it was recognized that ordinarily the only direct or immediate environmental impacts will be associated with the normal launch of the MER–2003 missions. These effects will include short-term impacts on air quality within the exhaust cloud at and near the launch pads, and the potential for acidic deposition from the exhaust cloud on the vegetation and surface water bodies at and near each launch complex, particularly if rain occurs shortly after launch. Neither short-term nor long-term impacts to threatened or endangered species are expected. No significant impacts are expected on nearby communities, and no impacts are expected to cultural, historical, or archeological resources as a result of either launch. Some short-term ozone degradation will occur along the flight paths as each launch vehicle passes through the stratosphere and deposits ozone-depleting chemicals from the exhaust products of the solid rocket motors.

From a cumulative environmental impact perspective, launch of the MER–2003 missions from CCAFS will principally contribute to exhaust emissions impacts on and near the launch pads. These impacts will include scorched vegetation and particulate deposition near the launch pads. On a short-term basis, the two MER–2003 launches will contribute to the addition of ozone depleting substances to the stratosphere.

There would be no environmental consequences associated with the No Action Alternative.

The consequences of potential accidents associated with launch of the two MER–2003 spacecraft are addressed in paragraph C below.

C. Assessment of the Analysis

The environmental impacts of normal Delta II and similar launches have been addressed in other National Environmental Policy Act (NEPA) documentation (*e.g.*, the U.S. Air Force's Evolved Expendable Launch Vehicle Program Final and Supplemental EISs, and NASA's environmental assessments for the New Millennium Program, the Stardust Mission, and the Space Infrared Telescope Facility). The primary environmental impacts of a normal launch will be associated with airborne emissions, particularly from the nine strap-on solid rocket motors used on the Delta II launch vehicles. Air emissions from the liquid propellant engines on the Delta II core vehicle, although large in magnitude, will be relatively inconsequential in terms of environmental effects. The air emissions from the Delta II launch vehicles will not create adverse impacts to air quality in the region and have been deemed insufficient to preclude Delta II operations. From a cumulative impacts perspective, the total contribution of the two MER–2003 launches to the average annual depletion of ozone will be extremely small (about 0.0025% for both launches on a global annual average basis).

The most severe propellant spill accident scenario postulated involves release of the entire contents of the Delta II second stage nitrogen tetroxide tank during propellant transfer. Because nitrogen tetroxide rapidly converts to nitrous oxides in the air, toxic effects of the release would be limited to the immediate vicinity of the launch pad. Workers performing propellant loading will be equipped with protective clothing and breathing apparatus.

The potential nonradiological short-term effects of a launch failure accident could include a localized fireball, falling fragments from explosion of the vehicle, release of unburned propellants and propellant combustion products, and for on-pad or very low altitude explosions, destruction or damage to nearby biota and brush fires near the launch pad. A launch vehicle failure on or near the launch area during the first few seconds of flight could result in the release of the propellants (solid and liquid) onboard the Delta II and the spacecraft. The resulting emissions would resemble those from a normal launch. A launch vehicle failure would result in the prompt combustion of a portion of the liquid propellants, depending on the degree of mixing and ignition sources associated with the accident, and somewhat slower burning of the solid propellant fragments. Falling debris would be expected to land on or near the launch pad resulting in potential secondary ground-level explosions and localized fires. After the launch vehicle clears land, debris from an accident would be expected to fall over the ocean. Modeling of accident consequences with meteorological parameters that would result in the greatest concentrations of emissions over land areas indicates that the emissions would not reach levels threatening public health. Some unburned solid and liquid propellants could enter surface water bodies and the ocean. Unburned solid and liquid propellants entering surface water bodies could result in short-term, localized degradation of water quality and toxic conditions to aquatic life. Such chemicals entering the ocean would be rapidly dispersed and buffered, resulting in no long-term impact on water quality and resident biota.

NASA’s cooperating agency, the U.S. Department of Energy (DOE), as owner of the RHUs, performed a nuclear safety risk assessment of potential accidents for the MER–2003 project. The EIS incorporates the results of DOE’s risk assessment. This assessment uses a methodology refined through applications to several previous missions and incorporates data from safety tests on the RHUs. The first step in the risk assessment is NASA's estimate of the probabilities of various launch system failures and the potential resulting accident environments that could threaten the RHUs and small-quantity radioactive sources onboard the rover. Then, the response of the RHUs and small-quantity radioactive sources to these accident environments is assessed, and an estimate is made of the amount of radioactive material that could be released for each accident environment. Finally, the analysis determines the potential consequences of each release to the environment and to the population. Accidents are assessed over all launch phases, from pre-launch through orbit escape; and consequences are assessed for both the regional population near the launch site, and to the global population in the event of an accident that results in a reentry from space.

The results of the NASA and DOE analyses indicate that the overall chance of an accident occurring during the launch of the MER–A spacecraft is about 1 in 31, and the overall chance of an accident occurring during the launch of the MER-B spacecraft is about 1 in 34 (based upon launch vehicle history and additional analysis). Most potential accidents would not present a threat to the RHUs onboard the spacecraft because of the rugged design of the RHUs and the addition of a third stage motor breakup system. For the MER–A launch, the chance of an accident in the launch area that releases any radioactivity is about 1 in 1,030. The overall chance of an accident that releases any radioactive materials to the environment is about 1 in 230. The accident probabilities for the MER–B launch are similar. Looking specifically at plutonium-238, the chance that an accident would result in the release of any plutonium-238 would be 1 in 5,000 for the MER–A launch and 1 in 5,800 for the MER–B launch.

The Cm-244 and Co-57 small-quantity radioactive sources and their mounting fixtures have relatively low melting temperatures compared to the plutonium in the RHUs, and their release in launch area accidents is assumed to be likely. Reentry conditions would also likely lead to the release of the small-quantity radioactive sources at high altitude. Safety testing and response analysis of the RHUs to accident environments indicate that only a very small fraction of early launch accidents could lead to potential releases of Pu-238. The RHUs are designed to survive reentry environments and subsequent surface impacts. The probability of an accident away from the launch area that could release small amounts of Cm-244 and Co-57, but not plutonium dioxide, is about 1 in 290.

The radiological consequences for each accident scenario were calculated in terms of (1) maximum individual dose; (2) potential for additional latent cancer fatalities (*i.e.*, the number of deaths due to cancer in excess of what the population would normally experience from other causes) due to a radiation release; and (3) land area contaminated at or above specified levels. Results are reported here for the MER–A mission. Results for the MER–B mission are similar.

If a launch-area accident resulting in the release of radioactive material were to occur, spectators and people offsite in the downwind direction could inhale small quantities of radionuclides, including Pu-238, Cm-244, and Co-57. In most cases, the amount of additional radiation exposure would be a very small fraction of the radiation exposure an individual receives from naturally occurring radiation in the Earth and from cosmic radiation. In the United States, the average annual radiation exposure is about 300 millirem from natural background sources. Human-caused exposures such as medical diagnostic X-rays add about 60 millirem to this annual average. In the event of a launch accident with a release of radioactive materials, the person with the highest exposure would typically receive less than a few tens of millirem. No health consequences would be expected with this level of radiation exposure.

The total radiological exposure to the regional and global populations from an accidental release at high altitude would also be very small. With either launch-area or orbital reentry accidents, the releases are predicted to be so small that no additional cancers would be expected among the launch-area or worldwide population.

The airborne radioactive materials released in a launch-area accident would be deposited downwind from the accident location. Most of the material released in the accident scenarios considered would be very small particles. The results of the DOE analyses indicate that the land area contaminated at levels that might require further action, such as monitoring or cleanup, is expected to be less than 0.5 square kilometer for postulated launch area accidents.

The radiological accident risk estimate for each mission (i.e. the total probability of releasing nuclear material times mean health effects) is reasonably bounded by a region up to 100 times higher and up to 100 times lower than the risk estimate. At the limits of this uncertainty region the associated risks have been determined to be acceptable. This region of uncertainty is similar to uncertainty analyses performed for previous mission risk assessments. No information was identified that would indicate that the accident risk estimate for this mission would exceed these limits. Therefore, no additional uncertainty analysis was conducted explicitly for this EIS.

Under the No Action Alternative NASA would not complete preparations for and implement the MER–2003 project. The No Action Alternative would not entail any of the environmental consequences associated with potential mission accidents.

Choice of Alternatives

In view of the small risks associated with the MER–2003 project, it is my intention to choose the Proposed Action, Alternative 1 (above, page 2), based on the following.

Alternative 1, continuing preparations for and implementing the MER–2003 project, including launch of MER–A on a Delta II 7925 in May or June, 2003, and launch of MER–B on a Delta II 7925 Heavy in June or July, 2003, enables the best return of scientific and technical information, makes most effective use of fiscal, human, and material resources, and avoids disruption of the Nation's program for the exploration of Mars.

The payload of instruments on each rover has been carefully selected to maximize collection of scientific data to meet MER–2003 project objectives. Scientists will be able to closely examine the physical, geological and chemical characteristics of the landing sites and determine their aqueous, climatic, and geologic histories. By reading the geologic record at each site, scientists can investigate the role water played there and determine how suitable the conditions would have been for life.

Operation of the rovers and their science instruments will also benefit the planning and design of future missions. Lessons learned during all phases of each MER–2003 mission (atmospheric entry, descent, and landing; initial deployment on the surface; real-time site traverse planning, execution and navigation; and science data collection) will provide valuable information for refining future mission designs and procedures.

Alternative 2, the No Action Alternative, is the environmentally preferred alternative. Under the No Action Alternative, planning and preparations for the MER–2003 project would cease and neither spacecraft would be launched during the 2003 launch opportunity to Mars. None of the science planned for the Proposed Action would be obtained and the objectives of NASA's planned follow-on missions to Mars would be adversely affected without the data to be obtained by the MER–2003 missions. NASA has no other missions at a stage of development that could be substituted for the Proposed Action and the launch opportunity for 2003 would be lost to NASA's overall Mars exploration effort.

The choice to continue preparations for and implement the MER–2003 project is fully consistent with the mandate of the National Aeronautics and Space Act to contribute to the expansion of human knowledge of phenomena in space.

D. Additional Information

In addition to the requirements under the NEPA and NASA policy and procedures, there is a separate and distinct Executive Branch interagency process for evaluating the nuclear launch safety of the project. Pursuant to paragraph 9 of Presidential Directive/National Security Council

Memorandum #25 (PD/NSC-25) a nuclear Safety Analysis Report (SAR), including an uncertainty analysis, was prepared and reviewed by an *ad hoc* Interagency Nuclear Safety Review Panel (INSRP), who then prepare a Safety Evaluation Report (SER). The Office of Space Science will be fully briefed on the outcome of the SAR and the MER–2003 INSRP evaluation prior to launch of the MER–2003 missions.

In the event there are significant differences between the risk assessment for the EIS and the results of the final safety analyses and evaluations, those differences will be considered and a determination made as to the need for any additional environmental documentation.

E. <u>Mitigation</u>

The only expected or immediate environmental impacts of the MER–2003 project are the same as those for every Delta II launch, and mitigation will accordingly be the same. This EIS primarily addressed possible radiological consequences of mission accidents. Regarding such possible radiological impacts, NASA, with expert technical assistance from DOE, the EPA, the U.S. Department of Defense, and other Federal agencies, and in cooperation with Florida State and local authorities, will develop a federal radiological emergency response plan. Key elements of monitoring and data analysis equipment will be pre-deployed to enable rapid response in the event of a launch anomaly. The plan, to be documented elsewhere, will address short-term monitoring and mitigation activities associated with each launch. Post-accident mitigation activities, if required, would be based upon detailed monitoring information and assessment. The plan will define the roles of the agencies involved.

<u>Decision</u>

Based upon all of the foregoing, it is my decision to complete preparations for launch of the MER–A mission in May or June, 2003, and launch of the MER–B mission in June or July, 2003, and to operate the missions.

Edward J. Weiler
Edward J. Weiler
Associate Administrator for
Space Science

1-30-03
Date

APPENDIX
RECORD OF DECISION
MARS EXPLORATION ROVER–2003 (MER–2003) PROJECT
ENVIRONMENTAL IMPACT STATEMENT (EIS)

NASA's Final EIS for the MER–2003 project was made available to the public on December 10, 2002. NASA could not take any action until the waiting period closed on January 15, 2003. During this period NASA received 161 pieces of correspondence, in the form of e-mails and letters, regarding the Proposed Action addressed in the EIS. Most of the correspondents expressed a desire that NASA reconsider the MER–2003 project and not launch the two spacecraft. Some correspondents expressed favorable support for the MER–2003 project. Many correspondents asked that NASA provide the total amount of radioactive material onboard each MER–2003 rover, and repeated the same statements made by others concerning the probability of a launch accident, the size of the potentially affected area, and the use of European solar cells. This appendix to the Record of Decision has been prepared by NASA to address these concerns.

Concern #1: What is the amount of plutonium-238, cobalt-57 and curium-244 used in each mission?

Response: As stated in the EIS (Section 2.1.2), a radioisotope heater unit (RHU) contains 2.7 grams (0.095 ounce) of plutonium dioxide. The EIS analyzed the use of up to 11 RHUs on each rover, which would yield a total of up to 29.7 grams (1.04 ounces) of plutonium dioxide on each rover. However, each rover will require only eight RHUs to provide the necessary thermal control on the surface of Mars. Thus, the actual amount of plutonium dioxide on each rover will be 21.6 grams (0.76 ounce). On average, the plutonium dioxide in the RHUs is 70.8% by weight plutonium-238. Therefore, the total amount of plutonium-238 on each rover will be 15.3 grams (0.54 ounce).

As described in the EIS (Section 2.1.1.5), the cobalt-57 and curium-244 are contained in two science instruments, the Mössbauer Spectrometer and the Alpha Particle X-ray Spectrometer, on each rover, and are referred to as "small-quantity radioactive sources" throughout the EIS. The amount of cobalt-57 used in the Mössbauer Spectrometer on each rover will be up to approximately 0.042 milligram ($1.4x10^{-6}$ ounce). The amount of curium-244 used in the Alpha Particle X-ray Spectrometer on each rover will be up to approximately 0.61 milligram ($2.1x10^{-5}$ ounce).

Concern #2: A statement is made in many of the letters that " … there is a 1 in 31 chance of accident of the May launch and a 1 in 34 chance of accident in the June launch", leaving the perception that NASA's analysis concluded that these are the probabilities of a release of radioactive material in the event of an accident.

Clarification: The chance of failure for the launch vehicles to be used for the May (MER–A) and June (MER–B) launches is indeed estimated to be 1 in 31 and 1 in 34, respectively, based upon launch vehicle history and additional analysis. However, a launch vehicle failure (accident) would not necessarily result in the release of radiological material. Table 2-4 of the EIS addresses the probabilities of release of radioactive material in the event of an accident. The overall chance that there could be an accident that releases any of the radioactive material (plutonium-238, curium-244, or cobalt-57) on the spacecraft is estimated to be 1 in 230 for the

MER–A launch and 1 in 240 for the MER–B launch. Looking specifically at plutonium-238, the chance that an accident would result in the release of any plutonium-238 would be 1 in 5,000 for the MER–A launch and 1 in 5,800 for the MER–B launch.

Concern #3: A statement is made in many of the letters that in the FEIS "… there is a map of Florida with a 60 kilometers radius shown as the “potentially affected area” of contamination", leaving the perception that the total area within a 60 kilometer radius of the launch site would be contaminated in the event of an accident.

Clarification: For purposes of the EIS analyses, the regional area of interest was considered to be the area encompassed within a 100 kilometer (62 mile) radius of the launch site, and the population within this regional area was estimated to be about 2.5 million people. This regional area was depicted on three maps in the EIS, one defining the region of interest (Figure 3-1), one depicting major population centers within the region (Figure 3-8), and the other for the Environmental Justice evaluation in Appendix B (Figure B-1). There is no area with a 60 kilometer radius discussed in the EIS.

If a launch area accident resulting in the release of plutonium dioxide and the small-quantity radioactive sources were to occur, the radioactive material would be dispersed based on the meteorological conditions at the time of the accident. The chance of an early launch accident that releases any radioactive material (plutonium-238, curium-244, or cobalt-57) is about 1 in 1,030. All of the 2.5 million people residing within the 100 kilometer (62 mile) radius area would not be exposed. Spectators and people offsite in the downwind direction could potentially inhale very small quantities of radionuclides. The person with the highest exposure would typically receive less than a few tens of millirem. (The average annual dose from naturally occurring sources of radiation in the United States is about 300 millirem per year.) No health consequences would be expected with this level of radiation exposure.

Concern #4: Why can’t NASA use the high-efficiency solar cells developed by the European Space Agency (ESA) for its Rosetta deep-space mission?

Response: Electrical power for operation of the MER–2003 rovers on the surface of Mars is provided by solar cells and batteries. The RHUs onboard the rovers are used only to provide heat to maintain the thermal environment of the batteries during the Martian night. In the EIS (Section 2.3) NASA assessed the feasibility of alternative (non-nuclear) methods for maintaining the rover’s thermal environment and determined that none of these techniques could provide the necessary thermal control for the required 90-sol duration of each rover.